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IV. *Aſtronomical Obſervations, made in the State of* Maſſachuſetts. *By Profeſſor* WILLIAMS.

Obſervations of the eclipſes of the ſun and moon, in the years 1761, and 1764; and from 1770 to 1784.

1. An obſervation of a lunar eclipſe, November 12, 1761, at *Waltham.*

THE weather was ſo cloudy that I could only make the following obſervations of this eclipſe.—

		Temp. app.
The ſhadow reached	*Kepler,*	$16^{h.}$ 59′ 0″
	Mare Vaporum,	17 7 40
	Tycho,	14 25
	Menelaus,	17 28
	Mare Criſium,	28 11
Total immerſion,		45 10

2. An obſervation of a lunar eclipſe, March 17, 1764, at *Waltham.*

The moon roſe behind a cloud that lay along the horizon, but ſoon began to appear: About $6^{h.}$ 10′ I ſaw her conſiderably eclipſed: *Tycho* was then covered.

The ſhadow reached	*Nectaris,*	$6^{h.}$ 30′
	Copernicus,	32
	Mare Vaporum,	43
	Menelaus,	55

The ſhadow reached	*Archimedes,*		56′	
	Mare Criſium,	$7^{h.}$	3	
covers	*Mare Criſium,*		17	
	Tycho begins to appear,	8	12	
leaves	*Mare Criſium,*		21	
End of the eclipſe,			39	54″

Theſe obſervations were made with a reflecting teleſcope about four feet in length: And the clock was adjuſted by a meridian line, and correſponding altitudes of the ſun.

3. An obſervation of a ſolar eclipſe, November 6, 1771, at *Bradford.*

The beginning of this eclipſe could not be obſerved, the weather being cloudy. At $1^{h.}$ 36′ 42″, it was evident that the eclipſe was begun. The clouds prevented alſo any obſervation of the quantity of the eclipſe: But I had a good obſervation of the end, which was at $3^{h.}$ 47′ 2″ apparent time.

4. An obſervation of a lunar eclipſe, April 6, 1773, at *Bradford.*

		Temp. app.		
Beginning of the eclipſe,		$14^{h.}$	32′	38″
The ſhadow reaches	*Grimaldus,*		40	43
	Mare Humorum,		41	53
covers	*Mare Humorum,*		47	38
reaches	*Tycho,*		52	23
	Kepler,	15	1	28
	Copernicus,		11	20
	Mare Tranquillitatis,		27	13
	Mare Fœcunditatis,		32	54

Mare

The ſhadow reaches	*Mare Serenitatis,*	42′ 15″
	Mare Criſium,	58 8
leaves	*Mare Criſium,*	$16^{h.}$ 43 23
	Mare Humorum,	45 23
	Mare Tranquillitatis,	52 25
	Tycho,	59 38
End of the eclipſe,		17 20 10

The laſt obſervation was attended with ſome uncertainty ;—the moon being near the horizon, and the day-light far advanced.

5. An obſervation of a lunar eclipſe, July 30, 1776, at *Bradford.*

This eclipſe was total : But the beginning of it, and the beginning of total darkneſs were inviſible at *Bradford,* both happening before the moon roſe. I was in hopes to have ſeen the end of total darkneſs, but was prevented by clouds. At $8^{h.}$ 30′ the ſky became perfectly clear, ſo that I had a good obſervation of the end of the eclipſe, which was at $9^{h.}$ 2′ 44″.

6. An obſervation of a ſolar eclipſe, June 24, 1778, at *Bradford.*

The beginning of this eclipſe could not be obſerved, the ſun being wholly covered with clouds. At $10^{h.}$ 8′ they broke away : And though often interrupted afterwards, I was able to note the following phenomena.

About $10^{h.}$ 16′, the horns of the ſun were obſerved to have an equal altitude, being in a line parallel to the horizon. At $10^{h.}$ 23′ the lucid parts of the ſun amounted to 2′ 45″ ; whence, as the ſun's apparent diameter was 31′ 34″, the eclipſed parts were 28′ 49″, or 10 digits and 57 minutes. This was very near the time of the greateſt obſcuration: But whether it was exactly ſo I could not determine, the ſun being obſcured juſt before and after this obſervation. At 10h. 25′ a large ſpot emerged from the ſhadow. At 10h. 59′ four other large ſpots were wholly within the lucid part. At the end of the eclipſe the ſky was become clear, and by a good obſervation I found this to be at 11h. 38′ 16″ apparent time.

During the eclipſe, there was a very ſenſible alteration in the ſtate of the *air*. A chill, and a damp were very generally felt. The mercury in the thermometer at 9h. 4′, juſt before the eclipſe began, was at 67°½. At 10h. 20′, it fell to 66°. At the end of the eclipſe it roſe to 73°; and at noon it was at 74°½.

As the time of the greateſt obſcuration came on, that part of the ſky which was free from clouds, changed from an azure blue, to a more dark and duſky colour: And the dew fell ſo faſt as to wet the paper we were uſing to a conſiderable degree.

As this eclipſe was *total* in ſome of the *ſouthern ſtates*, I was very deſirous to have it carefully obſerved in ſeveral places, in hope that a ſufficient number of obſervations might be collected to determine the exact path and limits of the ſhadow: And it was with much regret that I found myſelf prevented by the weather from making a more compleat obſervation.

7. An obſervation of a lunar eclipſe, December 3, 1778, at *Bradford*.

Beginning

	Temp. app.		
Beginning of the eclipſe,	$11^{h.}$	$41'$	$14''$
The ſhadow reaches *Mare Serenitatis,*	12	6	6
Copernicus,		13	53
Mare Tranquillitatis,		23	12
Mare Criſium,		28	15
leaves *Mare Imbrium,*	13	47	0
Mare Serenitatis,		54	0
Mare Criſium,		59	30
End of the eclipſe,	14	5	20

Theſe obſervations were made in a very favourable ſtate of the air.

8. An obſervation of a lunar eclipſe, and an emerſion of Jupiter's ſecond ſatellite, May 29, 1779, at *Bradford.*

The emerſion of the ſatellite was at	8	58	13
Beginning of the eclipſe,	10	15	41
The ſhadow touches *Tycho,*		35	15
Copernicus,		40	35
Mare Serenitatis,	11	0	6
Mare Criſium,		18	15
Beginning of total darkneſs,		28	39
End of total darkneſs,	12	50	41
The ſhadow leaves *Tycho,*	13	27	7
Mare Serenitatis,		38	57
Mare Criſium,		54	49
End of the eclipſe,	14	3	51

During the whole time of this eclipſe, the weather was very favourable for obſervation. All the obſervations made at *Bradford*, were taken with a reflector made by *Nairne*, magnifying about 55 times. The times were ſhewn by a good clock, carefully adjuſted by equal altitudes of the ſun, the day before and the day after the eclipſe.

9. Obſervations of a ſolar eclipſe, October 27, 1780, made on the eaſt ſide of *Long-Iſland*, in *Penobſcot-Bay*.

A total eclipſe of the ſun is a curious and uncommon phenomenon. From the principles of aſtronomy it is certain that a central eclipſe will happen, in ſome part of the earth, in the courſe of every year: But it is but ſeldom that a total eclipſe of the ſun is ſeen in any particular place. A favourable opportunity preſenting for viewing one of theſe eclipſes on October 27, 1780, the American Academy of Arts and Sciences, and the Univerſity at Cambridge, were deſirous to have it properly obſerved in the eaſtern parts of the State, where, by calculation, it was expected it would be total. With this view they ſolicited the government of the Commonwealth, that a veſſel might be prepared to convey proper obſervers to *Penobſcot-Bay*; and that application might be made to the officer who commanded the *Britiſh* garriſon there, for leave to take a ſituation convenient for this purpoſe.

Though involved in all the calamities and diſtreſſes of a ſevere war, the government diſcovered all the attention and readineſs to promote the cauſe of ſcience, which could have been expected in the moſt peaceable and proſperous times; and paſſed a reſolve, directing the Board of War to fit out the

Lincoln galley to convey me to *Penobſcot*, or any other port at the eaſtward, with ſuch aſſiſtants as I ſhould judge neceſſary.

Accordingly, I embarked October 9, with Mr. Stephen Sewall, Profeſſor of the Oriental Languages, James Winthrop, Eſq; Librarian, Forteſque Vernon, A. B. and Meſſ'rs. Atkins, Davis, Hall, Dawſon, Renſalear, and King, Students in the Univerſity.. We took with us an excellent clock, an aſtronomical quadrant of 2½ feet radius, made by *Siſſons*, ſeveral teleſcopes, and ſuch other apparatus as were neceſſary.

On the 17th we arrived in *Penobſcot-Bay*. The veſſel was directed to come to anchor in a cove on the eaſt ſide of *Long-Iſland*. After ſeveral attempts to find a better ſituation for obſervations, we fixed on this place as the moſt convenient we had reaſon to expect :* And on the 19th we put our inſtruments on ſhore, ſet up the clock and quadrant in a building facing towards the ſouth, near the houſe of Mr. *Shubael Williams*, where the following obſervations were made.

OCTOBER 20.

Correſponding altitudes of the ſun taken with a reflector fitted with vertical and horizontal wires.

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* As the officer who commanded at *Penobſcot*, in his anſwer to the application of the government, had limitted us to a time wholly inadequate to our purpoſe, from the 25th to the 30th of October, we were obliged to make a ſecond application for leave to enter *Penobſcot-Bay* Leave was granted, but with a poſitive order to have no communication with any of the inhabitants, and to depart on the 28th, the day after the eclipſe. Being thus retarded and embarraſſed by military orders, and allowed no time after the eclipſe to make any obſervations, it became neceſſary to ſet up our apparatus and begin our obſervations without any further loſs of time. In the courſe of which, we received every kind of aſſiſtance from Capt. *Henry Mowatt*, of the Albany, which it was in his power to give.

Time by the clock.

Eaſtern az.	Weſtern az.	Meridian.
8h. 15′ 44″	3h. 54′ 43″	12h. 5′ 13″,5
21 58	48 28	13
28 48	41 34	11
31 30	38 57	13, 5

Mean,	12	5	12, 75
Equation of altitudes,	+		17, 50
⊙'s center on the meridian,	12	5	30, 25
Clock too faſt,		5	30, 25

Meridian altitude of the ſun's upper limb, taken with the aſtronomical quadrant, 35° 15′ 45″

OCTOBER 21.

Correſponding altitudes of the ſun taken with a reflector.

Time by the clock.

Eaſtern az.	Weſtern az.	Meridian.
8h. 15′ 11″	3h. 58′ 20″	12h. 6′ 45″,5
18 45	54 46	45, 5
21 35	51 52	43, 5
28 28	45 5	46, 5
32 7	41 23	45
35 17	38 12	44, 5
45 53	27 36	44, 5

Mean,	12	6	45
Equation of altitudes,	+		17, 5
⊙'s center on the meridian,	12	7	2, 5
Clock gains in 24 hours,		1	32, 25

OCTOBER 22.

Thick fog all day. No aſtronomical obſervations. At 8h. 15′, A. M. I put the clock back 15′, and lengthened the pendulum.

OCTOBER 23.

Thick fog all day. No aſtronomical obſervations.

OCTOBER 24.

Correſponding altitudes of the ſun, taken with the quadrant.
Time by the clock.

	Eaſtern az.	Weſtern az.	Meridian.
	8h. 1′ 47″	3h. 44′ 58″	11h. 53′ 22″,5
	4 55	41 52	23, 5
	7 58	38 54	26
	11 31	35 23	27
	14 57	31 51	24
Mean,			11 53 24, 60
Equation of altitudes,			+ 16, 75
☉'s center on the meridian,			11 53 41, 35
Clock too ſlow,			6 58, 65

Meridian altitude of the ſun's upper limb, 33°51′43″

In the night I obſerved the meridian altitude of

Rigel,	37 16 15
Sirius,	29 19 0
Procyon,	51 30 26

OCTOBER 25.

Correſponding altitudes of the ſun, taken with the quadrant.

Time by the clock.

Eaſtern az.			Weſtern az.			Meridian.		
8h.	31'	17"	3h.	17'	19"	11h.	54'	18"
	35	4		13	31			17, 5
	36	43		11	53			18
	38	16		10	20			18
	42	4		6	28			16
	45	16		3	16			16
	46	0		2	33			16, 5
	47	38		0	53			15, 5
	49	16	2	59	11			13, 5
	57	16		51	8			12
	59	3		49	25			14
9	0	39		47	47			13

Mean,	11	54	15, 66
Equation of altitudes,	+		16, 63
☉'s center on the meridian,	11	54	32, 29
Clock too ſlow,		5	27, 71
Clock gains in 24 hours,			50, 94

Meridian altitude of the ſun's upper limb,	33°	31'	4"
In the night I obſerved the meridian altitude of			
Rigel,	37	16	15
Sirius,	29	19	6
Procyon,	51	30	30

OCTOBER 26.

Correſponding altitudes of the ſun, taken with the quadrant.

Time by the clock.

Eaſtern az.	Weſtern az.	Meridian.
8h. 30' 56"	3h. 19' 13"	11h. 55' 4",5
32 31	17 41	6
34 3	16 5	4
34 45	15 26	5, 5
36 25	13 46	5, 5
37 56	12 13	4, 5

Mean,	11 55 5
Equation of altitudes,	+ 16, 53
☉'s center on the meridian,	11 55 21, 53
Clock too ſlow,	4 38, 47
Clock gains in 24 hours,	49, 24

OCTOBER 27.

Correſponding altitudes of the ſun, taken with the quadrant.

Time by the clock.

Eaſtern az.	Weſtern az.	Meridian.
8h. 7' 18"	3h. 44' 30"	11h. 55' 54"
8 32	43 15	53, 5
9 14	42 32	53
10 48	40 56	52
12 6	39 40	53
15 41	36 15	58
17 23	34 26	54, 5
18 33	33 13	53
19 23	32 25	54
20 56	30 48	52
24 11	27 36	53, 5

Eaſtern az.	Weſtern az.	Meridian.
25' 25''	26' 18''	51'',5
26 21	25 33	57
29 39	22 16	57, 5
31 12	20 36	54
33 21	18 28	54, 5
35 5	16 48	56, 5
36 27	15 26	56, 5

Mean,	$11^{h.}$	55'	54, 33
Equation of altitudes,	+		16, 40
☉'s center on the meridian,	11	56	10, 73
Clock too ſlow,		3	49, 27
Clock gains in 24 hours,			49, 20

OBSERVATIONS OF THE ECLIPSE.

Four perſons obſerved the ſolar eclipſe with me. Profeſſor Sewall, James Winthorp, Eſq; Meſſ'rs. Dudley Atkins, and John Davis, two young gentlemen of the Univerſity, who had made good proficiency in mathematical ſtudies, and been pretty conſtantly employed in making obſervations for ſeveral days before.

At $8^{h.}$ 20', A. M. with an object-glaſs micrometer applied to a reflecting teleſcope of twelve inches focus, made by *Short*, I meaſured the ſun's diameter parallel to the horizon, and by a mean of ten obſervations, I found it 32' 17'', 33.

With a reflecting teleſcope of two feet focal length, made by *Short*, and a magnifying power of ninety times, I obſerved the beginning of the eclipſe at $11^{h.}$ 11' 8''.

Soon after I had noted the beginning, I adjuſted the micrometer to the direction of the ſhadow; and during the increaſe of the eclipſe, made the following obſervations on the quantity.

App. time.			Lucid Parts by the Micrometer.			Lucid Parts reduced.	
h.	′	″	Rev.	Parts.	Diviſ.	′	″
11	27	58	1	11	16	25	12, 8
	29	1		10	16	24	31, 8
	30	12		9	12	23	42, 5
	33	38		8	7	22	51, 0
	35	49		7	18	22	32, 6
	38	14		5	12	20	57, 9
	42	24		3	4	19	19, 3
	45	24		1	6	18	1, 2
	49	36	0	23	15	16	16, 3
	51	53		22	7	15	18, 8
	54	33		21	18	15	0, 3
	56	16		19	13	13	27, 8
	58	35		18	7	12	34, 4
12	0	48		17	19	12	17, 9
	4	0		16	10 d	11	18, 3
	6	52		13	7	9	8, 8
	9	3		12	2	8	17, 4
	12	48		10	15	7	21, 9
	13	38		9	16	6	42, 8
	17	26		7	2	4	51, 9
	19	36		6	17 d	4	41, 5
	21	24		5	14 d	3	54, 3
	22	51		4	18	3	21, 4
	25	13		2	10	1	42, 7
	26	50		1	13	1	7, 8
	28	48			12		24, 7

Immediately after the laſt obſervation, the ſun's limb became ſo ſmall as to appear like a circular thread, or rather like a very fine horn. Both the ends loſt their acuteneſs, and ſeemed to break off in the form of ſmall drops or ſtars; ſome of which were round, and others of an oblong figure. They would ſeparate to a ſmall diſtance: Some would appear to run together again, and others diminiſh until they wholly diſappeared. Finding it very difficult to meaſure the lucid part any longer, I obſerved again in the larger teleſcope, looking out for the total immerſion. After viewing the ſun's limb about a minute, I found almoſt the whole of it thus broken or ſeparated in drops, a ſmall part only in the middle remaining connected. Plate I. Fig. VII. This appearance remained about a minute, when one of my aſſiſtants, who was looking at the ſun with his naked eye, obſerved that the light was increaſing. At this time I could not ſee any appearance of an increaſe of the lucid part. At $12^{h.}$ 31′ 18″, it was evident that the broken parts of the ſun's limb began to increaſe and unite. I immediately applied to the micrometer and meaſured the chord of the lucid part, and found it amounted to 42° or 43° : This was from the extremity of each limb taken from the moſt diſtant parts that were viſible. I then meaſured the connected part of the limb, and found it to be 24° or 25°. As the light and limb were by this time very ſenſibly increaſing, I again began to meaſure the quantity of the lucid part, and made the following obſervations with the micrometer.*

App. time.			Lucid Parts by the Micrometer.			Lucid Parts reduced.	
h.	′	″	Rev.	Parts.	Diviſ.	′	″
12	33	36	0	1	11	1	3, 7
	35	48		3	1	2	5, 3
	38	13		4	8	3	0, 8
	40	18		5	13	3	52, 2
	45	24		8	15	5	59, 7
	47	21		10	19	7	30, 1
	49	7		11	2	7	36, 3
	51	55		12	11	8	35, 9
	54	13		14	17	10	10, 4
	56	15		15	3	10	22, 7
	58	0		16	5	11	8, 0
1	2	59		19	5	13	11, 4
	6	10		21	1	14	25, 5
	12	29	1	0	0	17	7, 8
	14	5		1	7	18	8, 3
	17	53		3	5	19	21, 4
	21	5		5	0	20	33, 3
	24	46		7	7	22	9, 9
	30	12		10	12	24	23, 5
	33	12		12	8	25	37, 5
	35	41		14	19	27	22, 3
	39	6		16	19	28	44, 6
	42	25		18	19	30	6, 8
	46	31		20	7	31	4, 4

The quantity of the lucid part being now become ſo large, I prepared to obſerve the end : And with the ſame teleſcope which I uſed at the beginning, I obſerved the end of the eclipſe at $1^{h.}$ 50′ 25″.

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* I ſuſpect there muſt be ſome inaccuracy in theſe obſervations. Some months after, upon examining the micrometer with which they were taken, I found ſome parts of it had been diſplaced.

From theſe obſervations it may be inferred, that the greateſt obſcuration was at $12^{h.}\ 30'\ 12''$: At which time the ſun's limb was reduced to ſo fine a thread, and ſo much broken as to be incapable of menſuration.

Profeſſor Sewall obſerved with an achromatic teleſcope of 4 feet, made by *Dolland*, magnifying 40 times.

The beginning by his obſervation was at $11^{h.}\ 11'\ 38''$. The end was not accurately aſcertained, being diſturbed in his obſervations by ſome of the ſpectators.

Mr. Winthrop obſerved with a reflecting teleſcope, made by *Nairne*, magnifying 55 times.

The beginning by his obſervation was at	$11^{h.}$	$11'$	$38''$
Shadow touches the ſpots on the N.W. limb,		29	28
Spots totally immerſed,		30	0
Shadow touches the firſt ſpot in the weſtern limb,		44	6
central ſpot,		46	8
eaſtern ſpot,		47	9
End of the eclipſe,	1	50	17 to 21$''$

D. Atkins obſerved the beginning and end of the eclipſe with a reflecting teleſcope of 12 inches focus, made by *Short*, magnifying about 55 times. His other obſervations were made with the teleſcope which I uſed to obſerve the beginning and end of the eclipſe. The following is his account of his obſervations.

Beginning of the eclipſe,	11	11	13

The

	h.	′	″
The ſhadow touched the center of a large ſpot on the weſtern ſide of the ſun's diſc,	11	30	12
The ſhadow touched the center of a long cluſter of ſpots on the weſtern ſide of the ſun's center,		44	7
The ſhadow biſects the large ſpot in the ſun's center,		46	24
The ſpot on the eaſtern limb of the ſun half immerſed,	12	27	1
The ſpot on the eaſtern limb of the ſun half emerged,		40	18
The long cluſter of ſpots on the weſtern ſide of the ſun half emerged,		40	28
The central ſpot half emerged,	1	7	1
The ſhadow left the center of the ſpot on the weſtern ſide,		43	4
End of the eclipſe,	1	50	28

J. Davis obſerved with the teleſcope on the quadrant. It gives a very diſtinct viſion; but it's magnifying power is but ſmall. His account of his obſervations is as follows.

Beginning,	11	11	16
Shadow firſt touched the largeſt ſpot in the cluſter on the N. W. limb,		29	10
wholly covered the ſame,		30	9
Shadow firſt touched a large ſpot near the center of the ſun's diſc,		46	14
wholly covered it,		46	53
Firſt ſpot began to appear,	12	39	54
wholly free of the ſhadow,		41	13
Central ſpot firſt appeared,	1	6	25
free of the ſhadow,		7	14
Shadow leaves the ſun,	1	49	58

To have a comparative view of the ſeveral obſervations, they are ſet down together in the following table.

Obſervers.	Beginning.	End.	Teleſcope made uſe of.	Magnifying power.
Mr. Williams,	$11^h\,11'\,8''$	$1^h\,50'\,25''$	2 feet reflector,	90
Mr. Sewall,	11 11 38		4 feet achromatic,	40
Mr. Winthrop,	11 11 38	1 50 17to21	1 foot reflector,	55
D. Atkins,	11 11 13	1 50 28	1 foot reflector,	55
J. Davis,	11 11 16	1 49 58	$2\frac{1}{2}$ feet achromatic,	ſmall.

Whilſt we were making the above obſervations, there was little wind, and no cloud to be ſeen. But the air was not perfectly clear, being a little thick, or hazy.

From the beginning of the eclipſe unto the time of the greateſt obſcuration, the *colour* and *appearance* of the ſky was gradually changing from an azure blue to a more dark or duſky colour, until it bore the appearance and gloom of night.

The degree of *darkneſs* was greater than was to be expected, conſidering the ſun was not wholly obſcured.—*Venus* appeared bright in the weſt; *Jupiter* was ſeen near the ſun; *Lucida Lyræ* near the zenith, and *Aridef* in the north-eaſt near the horizon, appeared very bright. Several others of the fixt ſtars were alſo ſeen whoſe ſituations were not particularly noted. Objects at a ſmall diſtance appeared confuſed; and we were obliged to make uſe of candles to count our clock. But as ſoon as the greateſt obſcuration was paſt, it was univerſally remarked, that the increaſe of the light was much more rapid than that of the darkneſs had been.

As the darkneſs increaſed, a *chill* and *dampneſs* were very ſenſibly felt. To aſcertain the quantity of *dew* that fell on a ſquare

foot,

foot during the eclipſe, we cut two pieces of very fine ſoft paper, exactly twelve inches ſquare. Having weighed them in a nice balance, we placed them on an horizontal board in the open air. Juſt after the greateſt obſcuration we weighed one of them again, and found it's weight was increaſed by the *dew* that had fallen upon it, 4½ grains *troy*. At the end of the eclipſe we took up the other, and found it's weight increaſed by the *dew* that lay upon it, but 3 grains; 1½ grain being evaporated as the light and heat of the ſun increaſed. By a ſimilar experiment, the quantity of *dew* that fell upon a ſquare foot the night before, was found to be 6½ grains; the night after the eclipſe, 7 grains. Thus in 1 hour and 19 minutes, when the light and heat of the ſun were rapidly decreaſing, there fell two-thirds as much *dew* as fell the night before, or the night after the eclipſe.

To determine what alteration might take place as to *heat* or *cold*, we made the following obſervations on Farenheit's thermometer, which was hung up in the open air, on the north ſide of a tree.

Time.	Therm.	Time.	Therm.
10h. 0′	52°	12h. 16′	53°
24	54½	20	52
11 14	57½	25	51
21	58	33	50
26	58	42	48
44	58	45	49
49	57	1 24	51
56	56½	29	52⅓
12 1	56	32	54
3	55	37	55
11	54	54	58

To this we may add, ſo unuſual a darkneſs, dampneſs and chill, in the midſt of day, ſeemed to ſpread a general amazement among all ſorts of animals: Nor could we ourſelves obſerve ſuch unuſual phenomena without ſome diſagreeable feelings.

THE LATITUDE OF THE PLACE,

Computed from the obſerved zenith diſtance of the ſun's upper limb.

OCTOBER 20.

Zenith diſtance of the ſun's upper limb,		54°44′15″
Refraction,	+	1 20
Sun's ſemi-diameter,	+	16 8
Sun's parallax in altitude,	—	7
Zenith diſtance of the ſun's center,		55 1 36
Sun's declination, ſouth,	—	10 44 22
Latitude, north,		44 17 14

OCTOBER 24.

Zenith diſtance of the ſun's upper limb,		56 8 17
Refraction,	+	1 25
Sun's ſemi diameter,	+	16 9
Sun's parallax in altitude,	—	7
Zenith diſtance of the ſun's center,		56 25 44
Sun's declination, ſouth,	—	12 8 43
Latitude, north,		44 17 1

OCTOBER 25.

Zenith diſtance of the ſun's upper limb,		56 28 56

Refraction,	+		1'	26''
Sun's ſemi-diameter,	+		16	10
Sun's parallax in altitude,	—			7
Zenith diſtance of the ſun's center,		56°	46	25
Sun's declination, ſouth,	—	12	29	21
Latitude, north,		44	17	4
Mean of the above,		44	17	6,33

The LATITUDE computed from the obſerved zenith diſtance of ſeveral ſtars.

Rigel.

Mean of zenith diſtances, taken Oct. 24 and 25,		52	43	45
Refraction,	+		1	14, 7
True zenith diſtance,		52	44	59, 7
Declin. S. Jan. 1, 1770, by *Greenwich Obſerv.*		8	29	0, 2
Decreaſe in 10 years and 299 days,	—			52,78
Aberration,	—			8,29
Nutation,	—			5,20
Apparent declin. ſouth, Oct. 25, 1780,	—	8	27	53,93
Latitude, north,		44	17	5,77

Sirius.

Mean of zenith diſtances, taken Oct. 24 and 25,		60	40	57
Refraction,	+		1	41, 2
True zenith diſtance,		60	42	38, 2
Declin. S. Jan. 1, 1770, by *Greenwich Obſerv.*		16	24	56, 1
Increaſe in 10 years and 299 days,	+			45,97
Aberration,	—			11,04

Nutation,

Nutation,	—			6″,90
Apparent declin. ſouth, Oct. 25, 1780,	—	16°	25′	24, 13
Latitude, north,		44	17	14, 07

Procyon.

Mean of zenith diſtances, taken Oct. 24 and 25,		38	29	32
Refraction,	+			45, 3
True zenith diſtance,		38	30	17, 3
Declin. N. Jan. 1, 1770, by *Greenwich Obſerv.*		5	47	55, 2
Decreaſe in 10 years and 299 days,	—		1	20, 5
Aberration,	+			4, 7
Nutation,	+			8, 1
Apparent declin. north, Oct. 25, 1780,	+	5	46	47, 4
Latitude, north,		44	17	4, 7
Mean of the above,		44	17	8, 1
Latitude from obſervations of the ſun,		44	17	6, 3
Latitude from obſervations of the ſtars,		44	17	8, 1
Mean of both,		44	17	7, 2

In computing the latitude I have made uſe of the table refractions inſerted in the Greenwich obſervations. But fro ſeveral obſervations I have reaſon to think that the refractio in *Penobſcot-Bay* are not uniform and regular; but that th vary very much with the winds and weather in that uncultiv ted part of the country.

As to our longitude, I could have wiſhed to have had ſom obſervations of the eclipſes of Jupiter's ſatellites, and of the oc

cultatio

cultations of the fixed ſtars by the moon. But no obſervations of this kind could be made. Comparing my obſervation of the beginning and end of the eclipſe with obſervations made at *Cambridge*, *Chelſea*, and *Beverly*, and thence computing the difference of meridians, I find our obſervatory on *Long-Iſland*, was 9′ 20″ to the eaſt of *Cambridge*.

The longitude of the place of our obſervation agrees very well with what we had ſuppoſed in our calculations. But the latitude is near half a degree leſs than what the maps of that part of the country had led us to expect. On this account our ſituation, inſtead of falling within the limits of the total darkneſs, proved to be very near the ſouthern extremity.

10. Obſervations of a lunar eclipſe, November 11, 1780, at *Cambridge*.

The clock was regulated by equal altitudes of the ſun, taken by Mr. Gannett and Mr. Mellen. At $8^{h \cdot}$ 40′, I meaſured the moon's diameter parallel to the horizon with an object-glaſs micrometer, and by a mean of ſeven obſervations, found it to be 30′ 45″,9.

	Temp. app.
Beginning of the eclipſe, by	
Mr. Williams, with an achromatic teleſcope magnifying 90 times,	10^{h} 21′ 9″
Mr. Gannett, with a reflector magnifying 55 times,	10 21 23
J. Dawſon, with a reflector magnifying 60 times,	10 21 37
End of the eclipſe, by	
Mr. Williams,	13 22 22
Mr. Gannett,	13 22 21
Mr. Mellen, with a reflector magnifying 55 times,	13 22 24

At the time of the greateſt obſcuration the quantity of the lucid part, as near as I could meaſure it with the micrometer, amounted to 5′ 39″, 2.—But this obſervation, and thoſe made on the end of the eclipſe, muſt be viewed as attended with ſome uncertainty. The ſhadow of the earth, throughout the whole eclipſe, was very ill-defined: And from the middle to the end of the eclipſe, the moon was partly obſcured by very thin whitiſh clouds, which made it extremely difficult to diſtinguiſh the limits of the ſhadow, or the exact time when it left the moon's limb.

11. Obſervations of a lunar eclipſe, March 28, 1782, at *Cambridge*.

Three gentlemen of the Univerſity obſerved this eclipſe with me:—James Winthrop, Eſq; Librarian, John Mellen, A. M. Mathematical Tutor, and Elijah Paine, A. B. The obſervations we made were as follow.—

Mr. *Williams's* obſervations.

	Temp. app.
Beginning of the eclipſe,	$14^{h}\,13'\,16''$
Shadow reaches *Tycho*,	28 58
Grimaldus,	31 3
covers *Grimaldus*,	37 51
reaches *Copernicus*,	15 4 10
Mare Tranquillitatis,	8 40
Tycho appears,	16 26 27
leaves *Tycho*,	28 19
Mare Criſium,	29 25
End of the eclipſe,	53 41
End of the penumbra,	55 51

Theſe obſervations were made with an achromatic teleſcope magnifying 90 times, made by *Nairne*. At 13$^{h.}$ 30′, I meaſured the moon's horizontal diameter with an object-glaſs micrometer applied to a reflecting teleſcope of 12 inches focus, made by *Short*, and by a mean of five obſervations I found it 33′ 12″. The greateſt obſcuration was at 15$^{h.}$ 34′ 33″, when the lucid part of the moon, meaſured by the micrometer, was 11′ 31″, amounting to 4 digits 11′: Whence the quantity of the eclipſe was 7 digits 49′.

Mr. *Winthrop's* obſervation.

	Temp. app.		
Eclipſe began,	14$^{h.}$	13′	42″
Shade reached *Tycho*,		28	5
Tycho wholly eclipſed,		30	24
Grimaldus,		33	27
Grimaldus quite eclipſed,		37	42
Inſula Ventorum eclipſed,		59	22
Copernicus,	15	4	6
Cuſps horizontal,		48	59
Tycho begins to emerge,	16	26	6
quite out of the ſhade,		27	49
End of the eclipſe,		53	15
End of the penumbra,		53	45

Mr. Winthrop obſerved with a reflector, made by *Nairne*, fitted with vertical and horizontal wires, magnifying 55 times.

Mr. *Mellen's* obſervation.

	Temp. app.		
Beginning of the eclipſe,	14h.	14′	5″
Shadow firſt touched *Mare Humorum*,		22	43
Sinus Epidemarum,		23	44
Tycho begins to immerge,		27	7
wholly immerged,		28	34
Grimaldus begins to immerge,		31	41
wholly immerged,		37	51
Lauſbergius begins to immerge,		49	46
Inſula Ventorum begins to immerge,		53	21
Copernicus begins to immerge,	15	3	5
wholly immerged,		14	1
Mare Criſium begins to immerge,		27	51
Tycho begins to emerge,	16	25	51
wholly emerged,		28	21
Mare Criſium wholly emerged,		29	51
End of the eclipſe,		54	36
End of the penumbra,		55	31

Theſe obſervations were made with an achromatic teleſcope, made by *Dolland*, magnifying 40 times.

Mr. *Paine's* obſervation.

Beginning of the eclipſe,	14	14	26
Shadow reaches *Grimaldus*,		32	16
covers *Grimaldus*,		35	59
reaches *Copernicus*,	15	2	54
Grimaldus begins to emerge,		38	23
is wholly emerged,		42	17

Tycho begins to emerge,	$16^{h.}$ 26′ 49″
is wholly emerged,	27 52
Mare Criſium wholly emerged,	29 18
End of the eclipſe,	53 11
End of the penumbra,	56 11

Mr. *Paine's* obſervations were made with a reflector, made by *Short*, magnifying 55 times: But this was the firſt eclipſe he had ever obſerved.

Theſe obſervations were made at the houſe of Profeſſor *Williams*. The times were ſhewn by an excellent aſtronomical clock, made by *Ellicott*, which was carefully regulated by correſponding altitudes of the ſun. The weather was very favourable for obſervation.

In lunar eclipſes the ſhadow is ſo imperfectly defined that the beginning and end can ſeldom be obſerved without an uncertainty of one minute, and ſometimes of two or three minutes. In this eclipſe, the circumſtances were favourable for obſervation.

To have a comparative view of the ſeveral obſervations, thoſe phenomena are ſet down in the following table, which were noted by each obſerver.

Phaſes obſerved by Meſſ'rs.	Williams,	Winthrop,	Mellen,	Paine.
Beginning of the eclipſe,	14^h 13 16″	14^h 13 42″	14 14′ 5″	14^h 14′ 26″
Shadow reaches *Tycho*,	28 58	28 5	27 7	
Grimaldus,	31 3	33 27	31 41	32 16
covers *Grimaldus*,	37 51	37 42	37 51	35 59
reaches *Copernicus*,	15 4 10	15 4 6	15 3 5	15 2 54
Tycho begins to emerge,	16 26 27	16 26 5	16 25 51	16 26 49
wholly emerged,	28 19	27 49	28 21	27 52
Mare Criſium wholly emerged,	29 25		29 51	29 18
End of the eclipſe,	53 41	53 15	54 36	53 11
End of the penumbra,	55 51	55 45	55 31	56 11

12. Obſervations

12. Obſervations of a ſolar eclipſe, April 12, 1782, at *Cambridge*.

We had not any compleat obſervation of the beginning of this eclipſe, being interrupted by ſmall fleeting clouds paſſing over the ſun. At $12^{\text{h.}}\ 10'\ 45''$, I had a clear view of the ſun, and could not ſee any appearance of the eclipſe. At $12^{\text{h.}}\ 11'\ 15''$, I diſcerned a darkneſs upon the weſtern limb, but could not determine whether it was occaſioned by a thin whitiſh cloud which was then paſſing over the ſun, or whether it was the beginning of the eclipſe. At $12^{\text{h.}}\ 11'\ 45''$, the cloud left the weſtern limb, and it was apparent that the eclipſe began ſome time before. From theſe circumſtances I think it probable that the beginning of the eclipſe was very near $12^{\text{h.}}\ 11'\ 15''$. Mr. *Paine* made the ſame remarks upon the beginning; but noted the darkneſs 5 or 6 ſeconds ſooner than I perceived it.

At the end of the eclipſe we had very good obſervations; the air being clear, and the ſky free from clouds. Theſe obſervations were as follow:

End of the eclipſe

	Temp. app.
By Mr. Williams, with an achromatic teleſcope magnifying 90 times,	$2^{\text{h.}}\ 51'\ 30''$
By Mr. Winthrop, with a reflector magnifying 55 times,	2 51 28
By Mr. Mellen, with an achromatic teleſcope magnifying 30 times,	2 51 29
By Mr. Paine, with a reflector magnifying 55 times,	2 51 15

At $12^{h.}$ I meaſured the ſun's horizontal diameter with an object-glaſs micrometer, fitted to a reflecting teleſcope, and by a mean of five obſervations found it 31′ 54″. At $1^{h.}$ 34′, the obſcuration was the greateſt: The lucid part of the ſun was then 19′ 9′; whence, the greateſt eclipſe was 4 digits 48′.

13. Obſervations of a lunar eclipſe, September 10, 1783, at *Cambridge*.

The moon roſe behind a cloud that lay along the horizon. At $7^{h.}$ 20′, I ſaw her totally eclipſed. The eaſtern part was of that duſky copper-colour which is uſual in total eclipſes: But the weſtern part was ſo obſcure as to be almoſt inviſible, except a circular appearance of light round her limb. At $7^{h.}$ 27″, the clouds broke away, and I had a good obſervation of the

End of total darkneſs at $7^{h.}41'53''$

In a few minutes the moon was again obſcured by clouds: But at $8^{h.}$ 15′, they diſperſed and left a very clear ſky; after which I made the following obſervations:

Mare Serenitatis wholly emerged,	8	22	38
Mare Tranquillitatis wholly emerged,		31	3
Mare Criſium begins to appear,		31	33
biſected,		33	38
wholly emerged,		35	43
End of the eclipſe,		42	8

Theſe obſervations were taken with an achromatic teleſcope magnifying 90 times: But the ſhadow did not appear to be very diſtinctly defined.

Mr. Mellen, with a reflecting teleſcope magnifying 55 times, made the following obſervations:

End

	Temp. app.		
End of total darkneſs,	$7^{h.}$	$41'$	$48''$
Langrenus wholly emerged,	8	34	4
End of the eclipſe,		42	3

Mr. Paine obſerved with an achromatic teleſcope magnifying 30 times. By his obſervation

The end of total darkneſs was at	7	42	18
Bright ſpot in *Mare Vaporum* wholly emerged,	8	14	28
Mare Tranquillitatis wholly emerged,		31	88
End of the eclipſe,		42	13

Both theſe gentlemen obſerved with me; and the times were taken by the ſame clock.

The laſt eleven eclipſes were all that could be obſerved in this part of *America*, from Jan. 1, 1770, to Jan. 1, 1784.

Obſervations of the eclipſes of *Jupiter's ſatellites.*

1782.		Temp. app.				
June	25,	$9^{h.}$	$48'$	$30''$	Em.	2d ſatellite.
July	2,	12	21	54	Em.	2d ſatellite.
	3,	12	9	53	Em.	1ſt ſatellite.
Aug.	27,	9	6	25	Em.	1ſt ſatellite.
	28,	9	3	49	Em.	2d ſatellite.
Sept.	12,	7	31	29	Em.	1ſt ſatellite.

Theſe obſervations were taken with an achromatic teleſcope magnifying about 300 times. If they are compared with the calculations in the Nautical Almanac, the *mean* will give $4^{h.}$ $44'$ $36''$ for the difference of meridians between the Royal Obſervatory at Greenwich, and the Univerſity at Cambridge in America.

Obſervations of the Tranſits of VENUS and MERCURY over the Sun, in the Years 1769, and 1782.

I. An obſervation of the tranſit of VENUS over the ſun, June 3, 1769, at *Newbury*.

The tranſits of Venus over the ſun are among the moſt uncommon and uſeful phenomena which aſtronomy ever preſents to our view. I had the happineſs of ſeeing that of 1761, at *St. John's*, in *Newfoundland*, attending the late excellent Dr. *Winthrop* in his voyage and obſervations at that place. That of 1769 I obſerved at *Newbury*, at the ſeat of *Triſtram Dalton*, Eſq; a gentleman of *Newbury-Port*.

The teleſcope I uſed was a reflector, made by *Nairne*, magnifying about 55 times; a good inſtrument, but not fitted with a micrometer, or with vertical and horizontal hairs, as I could have wiſhed. The clock was a very good one, and carefully adjuſted to apparent time by correſponding altitudes of the ſun.

The weather for ſeveral days before the tranſit had been dull and rainy; but the third of *June* proved favourable to our wiſhes. The air was uncommonly clear, and the ſky ſerene. About twenty minutes before the tranſit was expected, I began to keep my eye ſteadily fixed on that part of the ſun's limb on which the planet, by calculation, was to enter; an aſſiſtant, counting the clock in the mean time, while another ſtood by to write down the obſervations. Thus prepared, we waited with a kind of agreeable anxiety for the high ſatisfaction of ſeeing Venus on the ſun; a ſatisfaction I had once before enjoyed in viewing the tranſit of 1761, and which I knew muſt end with that of 1769. A ſmall irregularity on the ſun's limb ſeemed to denote the approach or firſt appearance of the planet. At $2^{h.}$ 30′ 14″ apparent time, I ſuſpected I ſaw *a ſmall diſturbance* on the ſun's limb: But the impreſſion was then ſo ſmall, irregular, and ill defined, that it was not till after ſeveral ſeconds that I was certain the tranſit was begun. The impreſſion increaſing and growing more diſtinct, I fixed on the time mentioned above as the time of the *external contact*. By obſervers, in the ſame ſtate of the atmoſphere, with teleſcopes and eyes equally good, and fixed on that part of the ſun on which the planet entered, I imagine this firſt impreſſion might have been obſerved to an agreement of five or ſix ſeconds.

Soon after Venus had firſt touched the ſun's limb, the whole of her diſc became viſible: She appeared circular, and was ſurrounded with a pale glimmering light, not very diſtinctly defined. From this appearance I concluded it would be impoſſible to fix upon the preciſe moment when her limb would be exactly coincident with that of the ſun, and therefore determined to wait till there ſhould appear a ſmall thread of light between them. As the *internal contact* drew near, the thread of light began to form, and ſeemed to dart on each ſide of the planet for ſeveral ſeconds without being fixed or ſettled. At $2^{h.}$ 48′ 44″, with a ſeeming uncertainty of not more than ſeven ſeconds, it became cloſed and fixed. Venus then appeared wholly within the ſun, ſeparated from his limb by a fine ſtream of light flowing gently round it. This I fixed upon as the *internal contact*. Not having a *micrometer*, or hairs fixed in the reflector, inſtead of making any further obſervations, we could only enjoy the pleaſure of viewing this curious phenomenon, and ſhewing it to a number of gentlemen who had aſſembled on the occaſion.

In the above account of the *contacts* the duration of the ingreſs or paſſage of Venus over the ſun's limb, is 18′ 30″; near one minute longer than in moſt of the *American obſervations*. By theory it ſhould be 18′ 56″; but as this muſt have been contracted fifteen ſeconds by parallax at the place of obſervation, the apparent duration of the ingreſs would be but 18′ 41″; that is, eleven ſeconds longer than it was made by obſervation. I much doubt whether it was poſſible to diſcern the planet ſo ſoon as eleven ſeconds after the firſt contact, when not a ſecond of its diameter had entered upon the ſun. It ſeems more probable that the *internal contact* was paſt before the thread of light appeared to me to be compleated.

The latitude of the place where this obſervation was made is 42° 47′, north. With regard to it's longitude, the mean of ſix obſervations of the eclipſes of *Jupiter's ſatellites*, give it 1′ 26″ in time eaſt of *Cambridge*.

II. An obſervation of the tranſit of MERCURY over the ſun, November 9, 1769, at *Salem*.

The tranſits of Mercury, though they are not of equal uſe in aſtronomy as thoſe of Venus, are yet of great advantage to perfect the elements of his theory, and to determine the longitude of places on the earth. I had an opportunity to obſerve one of theſe tranſits at the houſe of *Andrew Oliver*, Eſq; at *Salem*.

The only inſtrument we could procure was a reflecting teleſcope magnifying about 60 times. To aſcertain the time I was obliged to make uſe of a *watch*, which for ſeveral days was carefully regulated by the ſun's paſſage over the meridian.—— Taking the minutes from the watch, I counted ſeconds from one minute to another. And from the pains I took to be exact, I believe the time was well pointed out this way, though ſuch as an Aſtronomer would by no means chuſe.

At 2h. 54′ 40″ apparent time, Mercury came on the ſun's limb as it were in an inſtant, in the form of a clear, regular, well-defined black ſpot. The *internal contact* was equally inſtantaneous. At 2h. 56′ 0″, the thread of light cloſed to appearance in a moment, without a ſeeming uncertainty of one ſecond. The ſky being perfectly clear and ſerene, nothing could be better defined than the limbs of Mercury and the ſun: But the teleſcope did not admit of any further obſervations, either of the diameters of the ſun and Mercury, or the leaſt diſtance of their limbs.

The latitude of *Salem* is 42° 35′ north; and it's longitude is about 1′ 15″ in time eaſt of *Cambridge*.

III. Obſervations of the tranſit of MERCURY over the ſun, Nov. 12, 1782, at the Univerſity in *Cambridge*.

Two gentlemen of the Univerſity obſerved this tranſit with me: *James Winthrop*, Eſq; Librarian, and *Elijah Paine*, A. B.

The inſtruments which I uſed in obſerving this tranſit, were an achromatic teleſcope made by *Nairne*, with a magnifying power of 150; a reflecting teleſcope fitted with an object-glaſs micremeter made by *Short*, with a magnifying power of 60; and an aſtronomical clock made by *Ellicott*. To regulate the clock with the greateſt accuracy I took a large number of correſponding altitudes of the ſun every day the weather would permit from the beginning of *October*, and found by the moſt careful attention that it kept equal time very exactly: The greateſt error at any time not being more than two ſeconds in twenty-four hours.

On the 12th of November the weather was fair, but the air was not in the moſt favourable ſtate for obſervation. Viewing the ſun with an excellent achromatic teleſcope, I found the ſpots on the diſc well defined; but the limb appeared to have an irregular, tremulous motion. This tremor, or undulation of the ſun's limb, was of different degrees at different times; but it did not wholly ceaſe any part of the day.

At $9^{h.}\ 55'$, I began to keep my eye ſteadily fixed on that part of the ſun's limb on which the planet was to enter; and at $10^{h.}\ 6'\ 0''$ apparent time, I ſaw the firſt appearance of *Mercury*. The impreſſion ſeemed to be ſudden and inſtantaneous, and without any uncertainty as to the time. But the appearance was not like the contact of two circles, or like that of a well-defined black ſpot entering upon the ſun; but rather like a dark oval ſhadow inſtantly entering and mixing with the ſun's limb. Plate I. Fig. VIII. While Mercury was thus entering upon the ſun, no part of it was viſible but that which was within the ſun's diſc. It's figure appeared to be elliptical: The greater axis ſeemed to paſs through the point of contact, and to be about one-third longer than the other. This elliptical appearance of the planet made it impoſſible to determine when the limbs of the ſun and Mercury exactly coincided. I therefore eſtimated the *internal contact* by the firſt appearance of a ſmall thread of light between them. This took place at $10^{h}\,12'\,7''$. The elliptical appearance was then wholly gone, and Mercury appeared circular, and perfectly well-defined. But the tremulous motion of the ſun's limb was then ſo great, that this obſervation ſeemed to be attended with an uncertainty of eight or ten ſeconds.

When Mercury was wholly within the ſun, I applied myſelf to the micrometer to meaſure the diameters of the ſun and Mercury, and the leaſt diſtance of their limbs. By a mean of eight obſervations taken during the tranſit, I found the ſun's horizontal diameter to be $32'\,21'',85$: This was the ſame with the reſult of ſeveral ſimilar obſervations made a little before the tranſit began, and juſt after it ended. To aſcertain the diameter of Mercury, I made twelve obſervations at different times during the tranſit. The greateſt care was taken to have them accurate: And the mean of all the meaſures gave it $9'',247$.

In obſerving the leaſt diſtance of the limbs of the ſun and Mercury, I made the following obſervations:

Apparent time.			Leaſt diſt. of the limbs of ☉ & ☿.		
h.	′	″	°	′	″
10	31	53	0	0	12, 33
	30	16			16, 44
	41	22			18, 49
	45	49			22, 00
	47	0			22, 60
	48	32			22, 60
	54	42			18, 49
11	4	20			12, 00

I found conſiderable difficulty in meaſuring ſuch ſmall diſtances.—But the utmoſt attention was paid to theſe obſervations, as being ſome of the moſt uſeful and important of the whole: And I believe they were taken with as much exactneſs as the inſtrument would admit. Thoſe near the middle I eſteemed the moſt exact.

As Mercury approached the limb of the ſun I again uſed the achromatic teleſcope; and at $11^{h.}\ 23'\ 8''$, obſerved *the ſecond internal contact*. Mercury was then perfectly circular and well-defined; and the undulation of the ſun's limb leſs than before. This obſervation did not appear to me to be attended with an uncertainty of more than four or five ſeconds. While Mercury was paſſing the ſun's limb, it's form again appeared elliptical, and the ſame phenomena took place which were noted at the former contacts, but in a much leſs degree. Juſt before the end of the tranſit, the limbs of Mercury and the ſun appeared to be blended and mixed together. At $11^{h.}\ 29'\ 19''$, Mercury ſeemed inſtantly to break off, ſeparate, and diſappear. This obſervation I eſteemed the moſt exact of any I had made.*

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* America was the moſt favourable place for obſerving this tranſit: And the undulation of the ſun's limb ſeems to have been greater, in ſome parts of Europe, than it was here. On ſuch accounts the American obſervations may be of much uſe in the records of aſtronomy. By a letter from M. DE LA LANDE, dated Paris, February 14, 1783, I find they have been viewed in this light by the ROYAL ACADEMY OF SCIENCES AT PARIS. "J'ai recu, Monſieur, avec une extreme ſatisfaction vos lettres "avec les obſervations qui y etoient renfermées. Je les ai preſentée a l' Academie "des Sciences, qui m'a chargé de vous en faire ſes remercimens, et qui les a deſtinées a l' impreſſion. J' ai donné moime au journal des ſavans votre obſervation du paſſage de Mercure, qui m'a fait d' autant plus de plaiſir que notre obſervation de Paris etoit fort douteuſe a cauſe de l' ondulation des bords du ſolcil."

To aſcertain the diameter of the ſun by other meaſures, about $12^{\text{h.}}$ I made ſeveral obſervations of his paſſage over the meridian. Theſe obſervations were taken with a tranſit teleſcope, fitted with three vertical hairs. The times were ſhewn by a curious *watch*, which diſtinguiſhes to a quarter of a ſecond. The mean of ten obſervations gave 2′ 16″, 2, for the time of the ſun's paſſing the meridian. This, reduced to parts of a circle, and multiplied by the co-ſine of the ſun's declination, gives 32′ 24″, 20, for the ſun's apparent diameter.

Mr. *Winthrop's* obſervation.

The teleſcope Mr. Winthrop uſed was a large reflector, made by *Short*. It's apperture is eight inches, and it's focal diſtance forty-eight. It has four magnifying powers—120, 260, 380, and 500. The magnifying power Mr. Winthrop uſed was 260. With this he obſerved

	Temp. app.
The firſt external contact at	$10^{\text{h.}}$ 6′ 31″
The firſt internal contact at	12 13
The ſecond internal contact at	11 23 5
The ſecond external contact at	29 10

With regard to theſe obſervations it ſhould be noted, that the times in both our obſervations were taken by the ſame clock; but we obſerved at different parts of the houſe, and without any kind of communication together. The obſervations of the firſt external contact differ thirty-one ſeconds. Thoſe of the firſt internal contact are within ſix ſeconds. Thoſe of the ſecond internal contact differ but three ſeconds: And in thoſe of the laſt external contact there is no difference at all. The obſervation of the laſt external contact Mr. Winthrop ſuppoſes was attended with the greateſt certainty: And he noted thoſe optical phenomena which have been mentioned.

Mr. *Paine's* obſervation.

Mr. Paine uſed a reflector made by *Nairne*, magnifying 50 times. This teleſcope is fitted with vertical and horizontal hairs; and is ſo made that theſe hairs may be adjuſted to any ſituation; to obſerve differences of altitude and azimuth, or thoſe of right aſcenſion and declination.

By his obſervation, the firſt external contact was at 10h. 7' 7". The internal contact was not accurately noted.

During the tranſit, he made the following obſervations of the difference of right aſcenſion between the limbs of the ſun and Mercury: The hairs in the focus of the reflector being ſo placed that the upper limb of the ſun appeared to move along one hair, and of conſequence, the other was perpendicular to the Equator.

1.	Temp. app.
Sun's preceding limb at the hair,	10h. 25' 50"
Mercury's center at the ſame,	27 35
Sun's ſucceeding limb at the ſame,	28 6
2.	
Sun's preceding limb at the hair,	32 49
Mercury's center at the ſame,	34 32d
Sun's ſucceeding limb at the ſame,	35 6
3.	
Sun's preceding limb at the hair,	48 36
Mercury's center at the ſame,	50 13
Sun's ſucceeding limb at the ſame,	50 53

Sun's

4.	Temp. app.
Sun's preceding limb at the hair,	11h. 1′ 58″
Mercury's center at the ſame,	3 30
Sun's ſucceeding limb at the ſame,	4 15
5.	
Sun's preceding limb at the hair,	5 41
Mercury's center at the ſame,	7 11
Sun's ſucceeding limb at the ſame,	7 57
6.	
Sun's preceding limb at the hair,	13 59
Mercury's center at the ſame,	15 26
Sun's ſucceeding limb at the ſame,	16 15
Laſt internal contact,	22 5
Laſt external contact,	28 6

In reſpect to Mr. *Paine's* obſervations of the contacts we may remark, that they appear to have been carefully made, notwithſtanding they differ ſo much from thoſe made with much larger teleſcopes. The difference in the obſervations evidently aroſe from the difference of teleſcopes. Mercury was ſeen with an achromatic magnifying 150 times, 1′7″ ſooner at the firſt contact, and 1′ 13″ later at the laſt contact, than it was with this ſmall reflector. The mean of theſe, 1′ 10″, may be taken as the difference which aroſe from the difference of teleſcopes in obſerving ſo ſmall an object as Mercury, in ſuch a ſtate of the atmoſphere. Allowance being made for this difference, Mr. Paine's obſervations of the contact will be found to agree as well with the other obſervations of the contact, as they do with each other. The obſervations of the differences of right aſcenſion would be very little affected by this cauſe, and therefore do not want any correction.

From theſe obſervations it will be eaſy to compute all the circumſtances of this tranſit, and the principal elements of the theory of Mercury.

Thus, Plate I. Fig. IX. let the circle ÆAQ repreſent the ſun; NS the ecliptic; ÆQ a parallel to the equator; VA the apparent path of Mercury; NE part of Mercury's orbit. SA is a perpendicular to the equator; SE a perpendicular to the ecliptic; and SM a perpendicular to Mercury's viſible way. The middle of the tranſit will be when Mercury arrives at the point M; the ecliptical conjunction at E; and the conjunction in right aſcenſion at A: And N will repreſent the place of Mercury's aſcending node.

The middle of the tranſit is given by the obſervations of the contacts. Thus,

	Temp. app.
By my obſervations of the external contacts, was at	$10^h 47' 39'',5$
By thoſe of the internal contacts,	10 47 37, 5
My Mr. Winthrop's obſ. of the internal contacts,	10 47 39
The mean of which may be aſſumed as moſt exact,	10 47 38,66

The viſible conjunction of the ſun and Mercury in right aſcenſion, may be deduced from Mr. Paine's obſervations of their differences, &c. The reſult of theſe obſervations, as I have deduced them from calculation, are as follow:

Obſ.	App. Time.	Difference R. A. of ☉'s center, and ☿ in Time.	Diff. R. A. in Parts of a Circle reduced to the Equator.	Time of Conjunction of ☉ and ☿ in Right Aſcenſion.
1	$10^h 27' 35''$	$37''$	$8' 48'', 2$	$12^h 5' 55''$
2	34 32d	34, 5	8 12, 3	12 5 15
3	50 13	28, 5	6 46, 8	12 5 59
4	11 3 30	23, 5	5 35, 4	12 5 58
5	7 11	22	5 14, 0	12 5 40
6	15 26	19	4 31, 3	12 5 57
			Mean,	12 5 57, 33

The apparent diameters of the ſun and Mercury are alſo determined by obſervation.

By the micrometer meaſures, Mercury's diam. was	9″,247
The diam. of the ſun by the microm. meaſures was	32′ 21, 85
By the time of it's paſſing the meridian,	32 24, 20
The mean of which may be taken as moſt exact,	32 22, 96

The leaſt diſtance of centers is alſo had from obſervation.

By the micrometer meaſures this was	15 43, 70

To examine the obſervations made by the micrometer, I computed by trigonometry what the leaſt diſtance of centers would be by calculation from the obſervations of the contacts. The reſult gives the leaſt diſtance

By my obſervations of the external contacts,	15 44, 1
By thoſe of the internal contacts,	15 43, 5
By Mr. Winthrop's obſerv. of the internal contacts,	15 43, 6
The mean is the ſame as by the micrometer,	15 43, 73

From the obſervations of the diameters and leaſt diſtance of centers, we may compute the length of the apparent tranſit-line, and Mercury's viſible horary motion from the ſun. In the right-angled triangle SM*m*, we have SM the leaſt diſtance of centers, and S*m* the ſum of ſemi-diameters. Multiply the the ſum of S*m* and SM by their difference, the ſquare root of the product will be the length of M*m*. By ſuch a calculation (all the circumſtances of the obſervations being taken into conſideration) the length of the tranſit-line, eſtimated

By the external contacts, is	496″,2
By the internal contacts, is	423, 0

And hence,

By proportion, ☿'s viſ. horary mot. from the ſun was	5′ 57, 33

From theſe *data* we may determine the angle of Mercury's viſible way with the ecliptic, the geocentric latitude, and the time of the ecliptical conjunction. In the right-angled triangle SMA, SM is given, and MA is known by the viſible horary motion of Mercury from the ſun. Hence, we can find SA, and the angle MSA 26° 13′ 28″. ESA is the angle made by that parallel to the Equator which paſſes through the ſun's center at the ecliptical conjunction, and the ecliptic; and is equal to the ſun's declination at that time, 17° 52′ 55″. Subtract this angle from MSA, and we have the angle MSE, the angle of Mercury's viſible way with the ecliptic, 8° 20′ 33″. Again, in the right-angled triangle SME, we have SM, and the angle MSE; from which we can find SE and ME. The former is the geocentric latitude, and the latter is the difference between the middle of the tranſit and the ecliptical conjunction. By ſuch a calculation corrected by parallax, at the ecliptical conjunction the geocentric latitude of Mercury was 15′ 56″, 8: And the time of ecliptical conjunction, Nov. $12^{d.}$ $11^{h.}$ 10′ 58″.

In the above calculation, the parallax of Mercury from the ſun at the ecliptical conjunction, is ſuppoſed to be 3″, 09 in latitude, and 1″, 50 in longitude.

The geocentric latitude and the angle of Mercury's viſible way with the ecliptic being known, we can alſo determine the place of Mercury's node, and the inclination of his orbit to the plane of the ecliptic. If we aſſume Mercury's diſtance from the earth to be 67683, and his diſtance from the ſun 31198, his heliocentric latitude at the ecliptical conjunction will be 34′ 36″; his horary motion in the ecliptic, 15′ 18″, 21; and his horary motion in the ecliptic from the ſun, 12′ 47″, 01.

Then, in the the right-angled ſpherical triangle VSE, SE and the angle VES are known; from which we can find the ſide SV, 3° 55′ 33″. If this be increaſed in the ratio of 12′ 47″, 01 to 15′ 18″, 21, we ſhall have the ſide SN, Mercury's diſtance from the node, 4° 41′ 59″. Subtracting this from 7$^{s.}$ 20° 26′ 36″ the ſun's place at the time of ecliptical conjunction, (by Mayer's tables) we ſhall have the place of Mercury's aſcending node in ♉, 15° 44′ 37″.

Again, in the right-angled ſpherical triangle SNE, the ſides SE and SN are given: From theſe we can find the angle SNE the inclination of Mercury's orbit to the plane of the ecliptic, 7° 0′ 13″.

In computing the place of Mercury's node and the inclination of his orbit, the calculation chiefly depends on the angle of Mercury's viſible way with the ecliptic. This may be computed from the obſervations of the *contacts*. But a very ſmall error in thoſe obſervations, will produce a very conſiderable one in the deductions. It was therefore thought beſt to deduce it from the obſervations of *right aſcenſion*, which are equally convenient, and more numerous.